

Department of Homeland Security

DHS supports Arctic research through the U.S. Coast Guard, which operates polar icebreakers as national polar research assets for Arctic oceanographic expeditions of both government and nongovernment researchers.

U.S. Coast Guard

Icebreakers

The Coast Guard supports Arctic research through its operation of three polar icebreakers, USCGC *Polar Sea* and USCGC *Polar Star*, which serve as high-latitude research platforms in both the Arctic and Antarctic, and the new polar icebreaker USCGC *Healy*, which started Arctic science cruises in 2001. Support of Arctic research by the U.S. Coast Guard dates back to the 1880s, when voyages on revenue cutters were made by scientists, including the renowned naturalist John Muir on the Revenue Cutter *Corwin* in 1881 and others on the Revenue Cutter *Bear* commanded by Captain Michael Healy in the 1880s and 1890s. Arctic research aboard Coast Guard icebreakers intensified in the late 1960s and early 1970s, when the prospect of increased oil and gas exploration in the Alaskan Arctic required ecological baseline surveys in the Chukchi and Beaufort Seas. The Coast Guard icebreakers *Northwind*, *Burton Island*, and *Glacier* supported these cruises. In the 1980s these vessels were decommissioned as the Polar-class icebreakers joined the fleet.

Polar-Class Icebreakers

The two Polar-class icebreakers were designed to carry out a range of missions in the Arctic, including escorting non-icebreaking vessels through the ice, resupplying military and research bases, and supporting scientific operations. In recent years the role of the Polar-class vessels in research has expanded as more complex projects and larger science teams placed added requirements on these ships. This led to a major upgrade of their capabilities in 1987 through the Polar Science Upgrade Project, a five-year program to enhance the scientific support capabilities of

	Funding (thousands)	
	FY 02	FY 03
Arctic Science/Logistics Support	59,730	37,834
Extramural Science Support	30	30
Total	59,760	37,864

these vessels. Laboratories and living areas were expanded to allow up to 32 scientists and technicians to embark on scientific cruises. Upgraded oceanographic winches, new cargo and science gear handling systems, expanded lab spaces, new oceanographic instrumentation, and new communications and satellite data acquisition systems significantly improved the research capabilities of the Polar-class vessels.

Since 2001, severe Antarctic ice conditions have critically reduced the service life of the *Polar Sea* and *Polar Star*. The condition of *Polar Star* and *Polar Sea* will pose a challenge to the Coast Guard and stakeholders in the U.S. polar research program.

USCGC Healy

To meet the expanding needs of the future, the Coast Guard commissioned a new research platform designed primarily for Arctic science, though capable of work in the Antarctic as well. The new vessel, USCGC *Healy*, was built by Avondale Industries in New Orleans, Louisiana. *Healy* is 420 ft long, has a beam of 82 ft, and displaces 16,000 long tons. The maximum speed is 17 knots, with a range of 16,000 nautical miles at 12.5 knots. *Healy*'s primary mission is to function as a world-class high-latitude research platform. *Healy* is able to conduct scientific operations during all seasons in the Arctic, including wintering over for planned missions.

The scientific support capabilities of *Healy* substantially surpass those provided by the Polar-class icebreakers. The ship is able to accommodate

35 scientists on a routine basis and provide surge accommodations for up to 50. Over 5,000 square feet of science lab and support space is provided, including a main science lab, a wet science lab, a biological and chemical analysis lab, an electronics lab, a meteorology lab, and a photography lab. In addition *Healy* has five hydraulically operated cranes, two oceanographic winches, and a double-drum core/trawl winch. It also provides over 4,000 square feet of open deck space and 20,000 cubic feet of scientific storage space in three cargo holds. Installed bathymetric and oceanographic instrumentation includes a bottom profiling system, a Seabeam bottom mapping sonar system, an XBT data acquisition unit, and an acoustic Doppler current profiler. Lab spaces are equipped with



USCGC Healy enters the ice for the first time, April 2000.

a science data network providing 120 dual fiber-optic-connected Ethernet ports throughout the science spaces for real-time data transfer between data processors, workstations, and printers. In addition there is a dedicated Inmarsat-B with high-speed data transmission and e-mail capabilities for scientists.

After delivery on 9 November 1999 by Litton-Avondale Industries, *Healy* underwent a period of fitting-out availability and propulsion system repairs. The ship departed New Orleans on 26 January 2000 to conduct machinery, hull, and science suite testing. Initial warm-water trials were completed in March. Ice trials were conducted from April to June in Baffin Bay in the eastern Arctic. *Healy* performed well, with icebreaking performance exceeding design requirements of 3.0 knots through 4.5 ft of ice. The maximum thickness of unbroken level ice encountered was 5.5 ft, which *Healy* transited at a continuous speed of 2.6 knots. Ice ridges of 45 ft were broken through in

three runs. *Healy* transited the Northwest Passage in July and arrived at Seattle on 9 August. The ship was commissioned on 21 August 2000.

During the first science cruises in 2001, *Healy* conducted successful cruises in the eastern Arctic Ocean, including the North Pole.

Arctic Research Cruises

The Coast Guard's major Arctic research efforts supported during the past two years were the Arctic West Cruises aboard *Polar Star* and *Healy* in 2002, and the Arctic East and West Cruises aboard *Healy* in 2003.

USCGC Polar Star 2002

After returning from Operation Deep Freeze 2002 on 14 April and following shipyard and dockside repairs, *Polar Star* departed on July 9 for the Arctic West Summer 2002 (AWS-02) mission for the multi-year Western Arctic Shelf–Basin Interactions (SBI) project. These studies, funded by the National Science Foundation and the Office of Naval Research, were aimed at understanding the flux of carbon and water properties (nutrients, temperature, and salinity) from the surrounding continental shelf into the Arctic Ocean basins and their relation to climate dynamics. *Polar Star*'s effort was conducted in two phases.

SBI 2002 Mooring Cruise. The first 30-day phase of AWS-02 began 15 July with the science party, led by Dr. Thomas Weingartner of the University of Alaska, embarking from Dutch Harbor and then transiting to the northern edge of the Chukchi Sea to study physical oceanography. During the cruise, 13 moorings were deployed for measuring oceanographic parameters for a period of one year. Data were also collected from 80 casts using conductivity, temperature, and density (CTD) sensors and the rosette water sampler at different depths. In addition, 36 expendable probes (XCTDs) were launched. Institutions participating in Phase One included the University of Alaska Fairbanks, the Woods Hole Oceanographic Institute, the University of Washington, and the Scripps Institute of Oceanography.

SBI 2002 Chuckchi Borderlands Cruise. The Phase Two science party, led by Chief Scientist Dr. Rebecca Woodgate of the University of Washington, embarked from Barrow, Alaska, on 19 August for a five-week cruise that extended Phase One studies farther north and west into the Beaufort Sea. Water column samples were analyzed for chemical tracers, including radioisotopes and

chlorinated fluorocarbons (CFCs) to calculate the contribution to the Arctic Ocean from Arctic rivers and Pacific water masses and how these might be changing in response to climate dynamics. Gail Grimes, a high school science teacher participating in the Teachers Exploring Antarctica and the Arctic (TEA) project, was on the cruise. Her postings are online at <http://psc.apl.washington.edu/HLD/CBL/Teacher/Webcode/index.html>.

Phase Two ended with the collection of 126 CTD and water-sampling profiles and 40 XBTs. The mission also successfully deployed and recovered all of a series of current meter moorings along the northern edge of the Chukchi Sea. The current meter data were used to document the transport of Pacific waters and continental shelf materials into the Central Arctic Basin. The institutions participating in Phase II included the University of Alaska Fairbanks, the University of Washington, the Scripps Institute of Oceanography, the Lamont–Dougherty Earth Observatory, and Lake Stevens High School, Lake Stevens, Washington.

USCGC Healy 2002

On 27 April *Healy* sailed for the five-month AWS 2002 mission to support two multidisciplinary projects: the Western Arctic Shelf–Basin Interactions (SBI) project and the Marine Climate and Relative Sea Level Across Central Beringia project. Each project consisted of two phases, separated in time. General summaries of each of the phases are provided below, with links to more specific information.

Western Arctic Shelf–Basin Interactions (SBI). The SBI project is a multiyear, interdisciplinary program to investigate the impact of global change on physical, biological, and geochemical processes over the Chukchi and Beaufort Sea shelf basin regions in the western Arctic Ocean. The SBI project is jointly sponsored by the National Science Foundation and the Office of Naval Research and consists of 14 ongoing research projects. More information is available at the SBI website (<http://sbi.utk.edu>).

During the *Healy* SBI spring 2002 cruise (5 May–14 June), led by Dr. Jackie Grebmeier of the University of Tennessee, 12 interdisciplinary research projects participated, ranging from hydrographic measurements to biological studies of various trophic levels. Thirty-nine stations were occupied in the northern Bering Sea (test station), the Chukchi Sea shelf (Herald Valley transect), the Chukchi outer shelf to Arctic Basin lines (West Hanna Shoal and East Hanna Shoal transect lines),

stations near Point Barrow, and the Barrow Canyon transect.

Physical, biogeochemical, and biological measurements were made using a variety of sampling devices. Subsamples from four CTD/rosette casts were used for primary production, chlorophyll content, nutrients, particulate carbon, inorganic carbon, biomarkers, microzooplankton, and radioisotopes. Various nets were used to collect zooplankton for both population and experimental purposes. Benthic grabs and cores were used to collect benthic fauna and sediment samples for population, community structure, food web, and metabolism studies. Scientists were lowered to the ice to collect ice cores and make in-situ measurements of the ice. Shipboard marine mammal surveys from the bridge were made by the U.S. Fish and Wildlife Service. Helicopter operations were used for ice reconnaissance and for observing and photographing marine mammals.

The institutions participating included the University of Tennessee, the University of Miami, Old Dominion University, Oregon State University, the University of Alaska Fairbanks, the Lamont–Dougherty Earth Observatory, the University of Rhode Island, the Scripps Institution of Oceanography, the Bedford Institute of Oceanography, the Canadian Department of Fisheries and Oceans, the University of Texas, the University of Colorado, and the U.S. Fish and Wildlife Service.

During the *Healy* SBI summer 2002 cruise (17 July–23 August), led by Dr. Lee Cooper of the University of Tennessee, 15 interdisciplinary research projects participated, ranging from hydrographic measurements to biological studies of various trophic levels. Forty-five stations were occupied for hydrographic and biological sampling using the same systems described above for the *Healy* SBI spring 2002 cruise. Betty Carvellas, a high school teacher participating in the TEA project, was aboard. Her web site may be found at http://tea.rice.edu/tea_carvellasfrontpage.html.

The institutions participating included the University of Tennessee; the University of Miami; Old Dominion University; Oregon State University; the University of Rhode Island; the Scripps Institution of Oceanography; the Bedford Institute of Oceanography; the Canadian Department of Fisheries and Oceans; the University of Colorado; Woods Hole Oceanographic Institution; Essex High School in Essex, Vermont; Bigelow Laboratory; the University of Washington; ESRI; the University of South Carolina; Bermuda Biological

Station; the National Science Foundation; CBS News; the Associated Press; and *USA Today*.

Marine Climate and Relative Sea Level Across Central Beringia. Research for this project was led by Chief Scientist Dr. Lloyd Keigwin of Woods Hole Oceanographic Institute and colleagues Neal Driscoll of the Scripps Institution of Oceanography and Julie Brigham-Grette of the University of Massachusetts Amherst. The study, which focused on the relationship between the seafloor and the Bering Land Bridge that had connected Alaska and Russia, was the first coring program on the new icebreaker *Healy*. Additional measurements were made with hull-mounted and towed sonar arrays and with the CTD device. Further information may be found at <http://www.geo.umass.edu/beringia/index.html>.

During the first phase, which departed Nome on 16 June and returned on 6 July, measurements were made in three areas of the northern Bering Sea: the Navarin Pervents Canyon, the Bowers Ridge, and Briston/Bering Canyons. To assess potential coring sites, high-resolution maps of the seafloor bathymetry and sub-bottom were made with *Healy*'s multi-beam sonar and with a towed chirp sonar. At each coring station, samples of seafloor sediments were taken in the following order: a gravity core, then if conditions allowed, a multi-core, and finally a jumbo piston core (JPC). During the mission, data were obtained during 18 chirp sonar tows, 14 CDTs, 24 gravity cores, 14 multi-cores, and 9 JPCs, including one 80 ft long, a *Healy* record. The institutions involved in this phase include Woods Hole Oceanographic Institute, the Scripps Institution of Oceanography, the University of Massachusetts Amherst, Princeton University, the University of Kentucky, West Washington University, and the University of Delaware.

During the second phase, which departed Nome on 26 August and arrived in Barrow on 16 September, operations were identical except a fourth bottom sampling device, the vibracore, was added. During the mission, 3 gravity cores, 3 multi-cores, 23 JPCs, and 11 vibracores were taken. Institutions involved in this project include Woods Hole Oceanographic Institute, the Scripps Institution of Oceanography, the University of Massachusetts Amherst, Princeton University, the University of Kentucky, West Washington University, the University of Delaware, the University of Alaska Fairbanks, Old Dominion University, and the *New York Times*.

USCGC Healy 2003

On 13 June, *Healy* sailed toward the Panama Canal for a five-month mission circumnavigating the North American continent and conducting science operations in Baffin Bay, as well as north of Alaska. Science operations on *Healy* during AEWS 2003 included the Nares Strait Expedition, Northwest Passage Transit, Chukchi Cap Mapping, and SBI Mooring Cruise.

Nares Strait Expedition. The five-year Canadian Archipelago Throughflow Study (CATS) is a contribution to the U.S. Global Change Program. Further information about the CATS project may be found at <http://newark.cms.udel.edu/~cats>. The summer expedition to Nares Strait between northern Greenland and Ellesmere Islands contributed to the first-ever simultaneous tracking of the major freshwater fluxes out of the Arctic Ocean. The freshwater flux from the Arctic into the North Atlantic constitutes a key process that impacts the thermohaline ocean circulation and thus global climate. In conjunction with concurrent European studies east of Greenland, the Nares Strait Expedition tested the hypothesis that the freshwater fluxes through the Canadian Archipelago are similar in size to those through the Fram Strait between Greenland and Norway.

During this interdisciplinary cruise, led by Chief Scientist Dr. Kelly Falkner of Oregon State University and co-chief scientist Dr. Humfrey Melting of the Canadian Department of Fisheries and Oceans' Institute of Ocean Sciences, the main activities were deploying the Nares Strait pressure-measuring array, conducting hydrographic surveys of northern Baffin Bay and Nares Strait, recovering bottom-dwelling clams, coring into bottom sediments of Baffin Bay and Nares Strait, and conducting ADCP surveys to produce current velocity surveys of Nares Strait. Eighteen moorings were installed during deployment of the Nares Strait array, which records the pressure field that forces the fluxes of seawater through the strait. The array will be recovered in the spring of 2005. Coast Guard divers were used in the installation of the pressure-measuring array moorings as well as the collection of bottom-dwelling clams. Data from 79 casts of the CTD/rosette package were used to produce detailed hydrographic sections in northern Baffin Bay, Smith Sound, southern Kennedy Channel, and Robeson Channel. Additional casts were made in the heretofore unsampled Peterman Glacier Fiord and the Hall Basin. Four piston cores were taken in the area off Bylot Island, and one gravity core was taken in

Hall Basin. Two high school teachers, Gerhard Behrens and Robert McCarthy, were aboard. Their web sites may be found at http://newark.cms.udel.edu/~cats/healy_2003/update/gerhardindex.html and http://newark.cms.udel.edu/~cats/healy_2003/update/bobindex.html.

The institutions included Oregon State University; the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans; Adams Elementary School of Corvallis, Oregon; Governor Mifflin High School of Reading, Pennsylvania; the University of Delaware; the University of Hawaii; Environment Canada; the University of Victoria; the Bedford Institute of Oceanography; the University of Rhode Island; New York University; and the Canadian Ice Service, as well as a freelance journalist and a representative from the Grise Fiord Inuit village

Northwest Passage Transit. During the 19–30 August transit from Thule, Greenland, to Barrow, Alaska, *Healy* sailed the Northwest Passage by way of Prince of Wales Strait. A Ship of Opportunity (SOO) underway data collection effort was coordinated by David Forcucci, *Healy*'s Science Liaison. During the transit Chief Scientist Dale Chayes of Lamont–Dougherty Earth Observatory of Columbia University and David Monahan of the Canadian Hydrographic Office and the University of New Brunswick collected underway data including multibeam bathymetry. Collection of ADCP data and thermosalinographic data were supported by the U.S. Coast Guard. Expendable probe (XCTD) launches were coordinated by Dr. Kathy Crane of NOAA's Arctic Research Office and Dr. Eddy Carmack of the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans. Marine mammal and seabird observations were made by Marc Weber of the U.S. Fish and Wildlife Service and Stephanie Burkhart of the U.S. Coast Guard.

Institutions involved in this effort included the Canadian Hydrographic Office, the University of New Brunswick, the Institute of Ocean Sciences of the Canadian Department of Fisheries and Oceans, the Lamont–Dougherty Earth Observatory of Columbia University, NOAA's National Marine Fishery Service, NOAA's Arctic Research Office, the National Ice Center, the Canadian Ice Service, the U.S. Navy Arctic Submarine Laboratory, Mississippi State University, Brookhaven National Laboratory, the U.S. Fish and Wildlife Service, the U.S. Coast Guard, and the University of Delaware.

Chukchi Cap Mapping Cruise. The purpose of the next phase of AEWS 2003, a ten-day cruise led

by Chief Scientist Dr. Larry Mayer of the University of New Hampshire, was to map the seafloor north of Alaska for use in future EEZ claims. Under Article 76 of the U.N. Convention on the Law of the Sea, a country may claim rights to the seafloor beyond the normal EEZ limit. Key pieces of evidence to support a claim are the locations of the 2,500-meter depth contour and the foot of the continental slope. Although the U.S. has not ratified the convention, it is gathering data to support future claims. While the U.S. has made significant progress in temperate zones, this is the first Law of the Sea bottom mapping survey in the Arctic Ocean.

During the multibeam sonar survey of the continental slope north of Alaska, 1,530 nautical miles of the 2,500-meter-depth contour were mapped, and a new seamount, subsequently named Healy Seamount, was discovered. In addition, the cruise observed water depths greater than 4,000 meters, depths not previously measured in the Amerasian Basin. Before this *Healy* cruise, charts of the Arctic bottom showed only a small knoll where scientists discovered the seamount, which abruptly rises more than 3,000 meters from the ocean floor to approximately 925 meters of depth. During this cruise, it was demonstrated that an icebreaker's multibeam sonar could successfully map the seafloor while the icebreaker is breaking ice.

The cruise also added important information about ice age glaciation and past climates. Randomly oriented seafloor scours, mapped at depths of 300–400 meters, gave evidence of large icebergs scraping the seafloor. Parallel flutes, or grooves mapped at greater depths, provided clues to the motion of huge ice sheets creeping across what is today the continental shelf. A sediment core from the continental slope will be studied for insights into past periods of climate variability. Additionally, temperature and salinity data at stations spread across the survey area were collected to study water masses and circulation. Further information is available at <http://www.noaanews.noaa.gov/stories2003/s2137.htm> and <http://www.ccom-jhc.unh.edu/healy/index.htm>.

Scientists were from the University of New Hampshire, the Lamont–Dougherty Earth Observatory of Columbia University, NOAA's Arctic Research Office, NOAA's Office of Exploration, the Naval Research Laboratory, the U.S. Navy Arctic Submarine Laboratory, the University of Stockholm, the Geological Survey of Denmark and Greenland, and the Danish Hydrographic Agency.

SBI 2003 Mooring Cruise. During the period 11 September to 18 October, Chief Scientist Dr.

Rebecca Woodgate of the University of Washington led a cruise in support of the SBI project. After recovering moorings that had been on the ocean floor since the 2002 deployment by *Polar Star*, scientists transferred data from the array's sensors and then redeployed the moorings. Sonobuoys were deployed for recording sounds from whales. The cruise also conducted CTD, ADCP, and multibeam surveys; net tows; and remote determination of plankton concentration using a video plankton recorder (VPR). During the cruise there were 14 mooring recoveries and 15 mooring deployments. Extensive data were collected during 321 CTD casts, 34 VPR casts, 11 net tows, 63 XBTs, 70 sonobuoys, and 35 days of ADCP and multibeam surveys.

The institutions included the University of Alaska Fairbanks, the Woods Hole Oceanographic Institute, the University of Washington, the Scripps Institute of Oceanography, the University of Maryland, Brookhaven National Laboratory, Earth and Space Research, the University of Delaware, the Lamont–Doherty Earth Observatory, Louisiana State University, NOAA, and the University of New Hampshire.

International Ice Patrol

The Coast Guard International Ice Patrol (IIP), located in Groton, Connecticut, participated in two research programs, one an iceberg-detection study using satellite-borne radar systems and the other a cooperative research program with the Canadian Ice Service (CIS) to test the accuracy

of iceberg drift models, including one recently developed by CIS. Although this research occurred south of the Arctic Circle, it has direct relevance to high-latitude navigation and is an integral part of the Coast Guard's Marine Science Program.

The iceberg-detection effort is part of the Global Monitoring for Environment and Security (GMES) program, which is co-led by the European Space Agency (ESA) and the European Commission (EC). IIP is participating as an end user in the program called Northern View: Earth Observation for Northern Monitoring, which is led by C-CORE, a research and development corporation located in St. John's, Newfoundland. Under the program, C-CORE provides IIP the location of icebergs obtained from the analysis of images by the synthetic aperture radar on two satellites, Canada's RADARSAT-1 and ESA's ENVISAT. During 2003, IIP compared the satellite observations with observations from other sources, including IIP's aerial reconnaissance. This program will continue throughout the 2004 iceberg season.

The second program is a joint IIP and CIS effort to evaluate the accuracy of the operational iceberg drift model used by the two organizations and a new model created by CIS. In 2003, IIP deployed a satellite-tracked transponder onto a fragment of an ice island and tracked its movement for 14 days. The movement of the ice island fragment was compared with model predictions. In 2004, additional ice beacons will be deployed by aircraft onto icebergs, and their observed movement will be compared to the model predictions.